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Research Article

Impact associated with water sources: An environmental analysis

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Abstract

This analysis addresses the main stressors that affect water sources in the Combeima watershed, evaluating human activities such as subsistence mining, deforestation, erosion and the use of pesticides that impact the quality and availability of water resources. In addition, the effects of these threats on aquatic ecosystems and local communities are considered, proposing management and conservation strategies to promote sustainability in sustainable development in the region. Scientific information on the impacts of anthropogenic activities in this basin is limited. The research was divided into two phases: the first, in which the biological, socioeconomic and management systems of the area were analyzed from an ecosystem perspective, and the second, in which the DPSIR methodology was used to identify possible negative impacts on tourists. The main driving forces exerting adverse effects on the Combeima basin are pollution from subsistence mining, river bathing, pesticide use in agriculture, road saturation, souvenir collecting, tourism, urbanization, soil erosion, and deforestation, with a total of 12.9% threats, with high threats of 6.3%, medium threats of 6.3%, and low threats of 0.3%. These results allow government entities to take conservation measures that should include local stakeholderrs in the implementation to maintain the well-being of generations and avoid biodiversity loss in the Combeima basin.

Key words: Conservation, deforestation, DPSIR, environmental impact, road saturation, tourism

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Introduction

Since several years, the National Parks Unit of Colombia has promoted ecotourism as a strategy to conserve natural resources in protected areas, considered one of the ecotourism destinations with the most significant interest for travel and nature lovers. Ecotourism, is viewed as a source of sustainability, both for the protected area and for local communities, by generating economic income and employment (National Natural Parks of Colombia 2017). It's also true that, unplanned and/or inadequately managed ecotourism can cause serious adverse impacts on the environment and communities, deteriorating and degrading the natural resources on which they depend, especially wild plants and animals (Cubillos and Jiménez 2011).Within the National Parks area of Colombia is the Combeima river basin, which has traditionally been used as the main source of

water supply for the aqueduct of the city of Ibague and some irrigation systems in the region, and as ecosystem services for recreation, leisure and scenic beauty for the Ibague population (National Natural Parks of Colombia 2017).

Currently, concepts such as sustainable tourism and ecotourism are often confused and conflated, as the two are closely linked. However, some aspects allow us to differentiate the essence of each. The tourism activity developed in the Wildlife Refuge from the supply side is under the characteristics of ecotourism, while from the perspective of demand it is under the parameters of responsible tourism; therefore, if we consider supply and demand together, then we would be facing a modality of nature tourism under parameters of sustainability (Guzman et al. 2016).

Sustainable tourism, according to the UNWTO, is defined as tourism designed to improve the lives of local people, provide a higher quality of experience for visitors, maintain the quality of the destination's environment, achieve higher levels of economic profitability for the local population through tourism activities, and ensure the achievement of profits for local businesses (UNWTO 1998). Ecotourism is defined as a type of specialized tourism activity developed in conserved natural environments, with the essential motivation of visitors being to observe, learn, discover, experience, and appreciate biological and cultural diversity, with a responsible attitude to protect the integrity of the ecosystem and promote the well-being of the local community. Ecotourism increases awareness regarding the conservation of biodiversity, the natural environment, conserved natural spaces, and cultural assets, both among the local population and visitors, and requires special management processes to minimize the negative impact on the ecosystem (Congress of the Republic 2020).

Environmental impact involves the adverse effects on ecosystems, climate and society due to activities such as excessive extraction of natural resources, improper waste disposal, emission of pollutants and land use change, among others ((André et al. 2004). Ecotourism, like any other activity that is not well regulated, can generate some adverse impacts on the environment that can affect the biodiversity and communities (Serrano 2011). Visitor impacts have been identified by protected area managers in developing countries (Alderman 1991; Giongo et al. 1994). Trails and recreation areas (e.g., campsites, picnic areas, or attractions) are of particular concern since recreational activities such as hiking and livestock viewing are very popular among tourists and because trails and recreation areas are often the most used by visitors to protected areas (Backman and Potts 1993; Wight 1996), often with a reduction in wild populations, especially for rare plants (Perrino et al. 2022) and animals (Villordo et al. 2010; Ávila et al. 2011).

The impact on resources may vary depending on the characteristics of the site, the prevailing conditions, and the types of activities practiced (Bushell 2003). However, excessive tourism in Protected Areas (PAs) induces an increase in the deterioration of natural and cultural resources (Leung et al. 2018).

Environmental assessments employ scientific tools to evaluate, predict, or calculate the ecological status of an ecosystem following standardized guidelines (Loiseau et al. 2012). Currently, these tools consider the interactions of biophysical and human components, as well as the use of services by societies that human activities can directly or indirectly impact. One of these assessment tools corresponds to the DPSIR framework, which integrates various components and mainly allows for a simple assessment of the state of ecosystems.

The Combeima basin, located in a privileged natural environment, is a tourist destination that attracts visitors seeking nature-based experiences and connections. However, the growth of tourism has led to a series of impacts and effects that may compromise both the environment and the quality of life of its local inhabitants (National Natural Parks of Colombia 2017). Hence the nature, the type and the powerfulness of the pressures, such as grazing, fire, waste disposal, especially on sensitive habitats has to be considered (Wagensommer et al. 2017; Ben Mahmoud et al. 2024)

This research paper evaluates the impacts associated with vital water sources, helping identify and understand the consequences of tourism on the biodiversity, water resources, and cultural heritage of the Combeima basin. Through the DPSIR analysis, some management strategies can be identified that promote sustainable tourism, balancing economic development with environmental conservation and the protection of cultural identity. This evaluation of tourism impacts becomes an essential tool to ensure that the Combeima basin remains a place of natural beauty and wealth, benefiting both tourists and the local communities who inhabit the area.

Methodology

Study area

The study area is the Combeima river basin, which is located in the city of Ibagué, in the Department of Tolima (Colombia), between the coordinates 04°19'30”–04°39'57"N, 75°10'11”–75°23'23"W, on the eastern flank of the central mountain range of the Andes in Colombia and is made up of three districts: Cay, Villa Restrepo and Juntas, which is home to more than 25 hamlets, its climate can vary significantly due to its altitude, which ranges between 1400 and 4200 m.a.s.l., with an area of 27,421 ha and a length of 57.7 km, the average annual rainfall is 1816 mm and the average temperature is 17 °C. There are intertwined mountains that house water tributaries with waterfalls, tropical forests, humid forests, Andean forests and even the important paramos. With biophysical conditions and its tourist appropriation, it is configured as a potential area for the development of nature tourism in the city of Ibague and the department of Tolima (Fig. 1) (CORTOLIMA 2019).

The five groups of protected areas of the Combeima Canyon are located in the districts of Juntas (3,486.01 ha) and Villa Restrepo (2,300.58 ha), North Hills of Ibague (9,130.5 ha), and the Civil Society Nature Reserve (184.2 ha), for a total of 15,101.29 ha. (Fig. 1). The study sites were selected to evaluate a variety of conditions that affect the type, severity, assessment, and management of visitor-generated impacts (CORTOLIMA 2019).

Methods

The DPSIR (Drivers, Pressures, State, Impacts and Responses) model is a management tool that recognizes and examines the origin and consequences of environmental problems and can improve decision-making by stakeholders and government (Kelble et al. 2013). It consists of five parameters: Driving Forces, Pressures, State, Impacts, and Responses (Ehara et al. 2018).

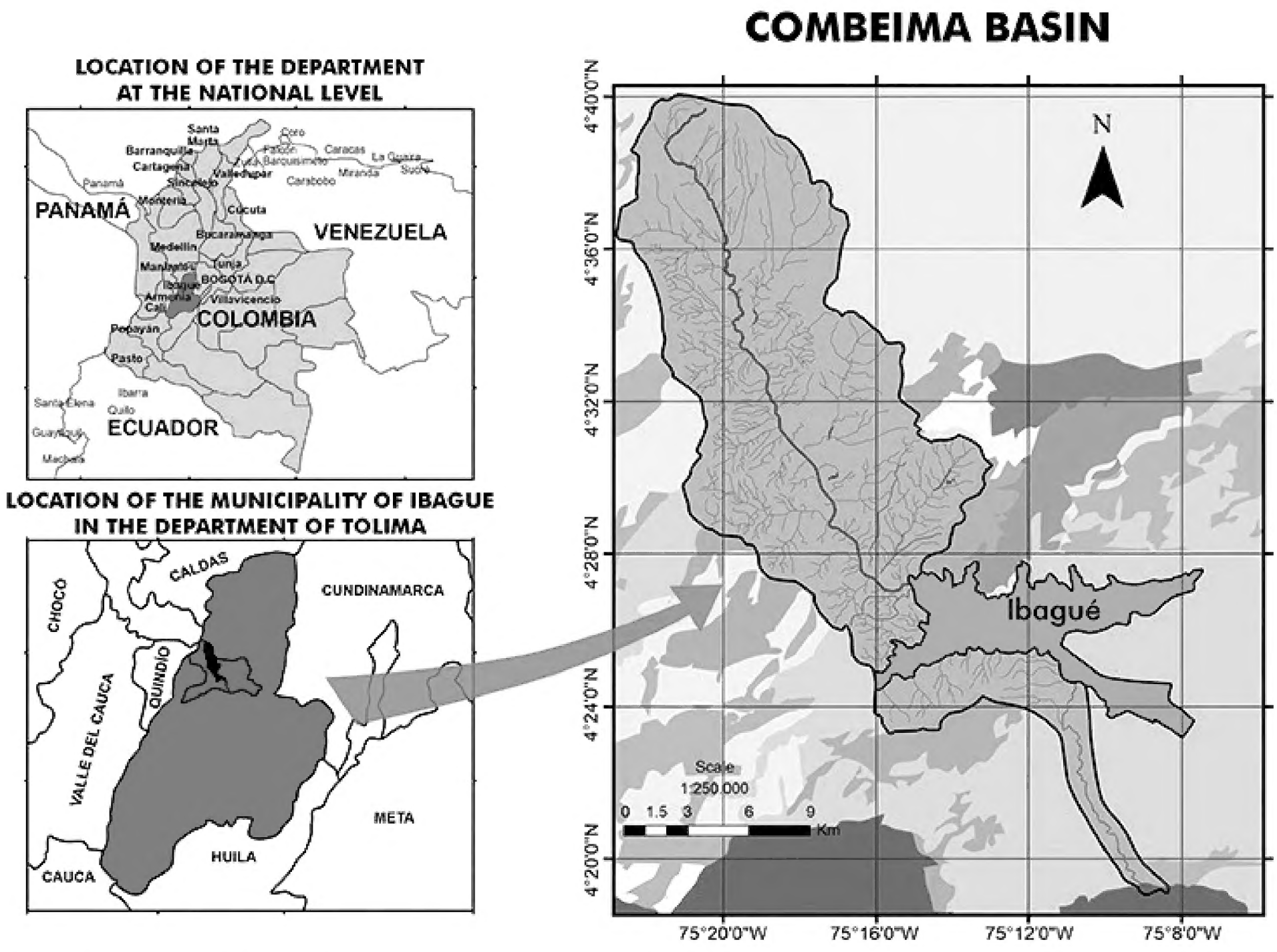

Figure 1. Location of the Combeima basin. Source. Agustín Codazzi Geographic Institute, P.O.T.

Drivers (D: Driving) include social, demographic and economic growth activities that generate pressures on ecosystems. Pressures (P: Pressure) are human-dependent activities or processes that have the potential for adverse effects (Impacts); State (S: State) refers to changes in ecological integrity, including alterations in the physical, biological and chemical conditions in a specific area. Impacts (I: Impacts) refer only to human welfare (socioeconomic system); and the responses (R) refer to political actions and programs led by institutions, community and government (Müller and Burkhard 2012; Pinto et al. 2013; Elliott et al. 2017).

The Combeima basin is a vital ecosystem facing significant challenges such as deforestation and mining pollution. To effectively address these problems, it is essential to apply the DPSIR methodology (Drivers, Pressures, State, Impact, and Response), which helps to understand the interactions between human activities and the environment. However, it is crucial to broaden this analysis by placing greater emphasis on private sector responses, alongside government actions, in order to improve long-term sustainability in the region.

Drivers in the Combeima basin include economic, social, and demographic factors that encourage the use of natural resources. Economic growth and demand for agricultural and mineral products are key drivers. Here, the private sector can play a crucial role by adopting more sustainable practices. For example, agricultural companies can implement sustainable farming techniques

that reduce pressure on natural resources, while mining companies can explore less invasive alternatives.

Private sector pressures, such as intensive agriculture and mining, significantly influence the environment. These pressures translate into ecosystem degradation, water pollution, and biodiversity loss. Companies can mitigate these pressures by adopting clean technologies and environmental management practices. For example, implementing environmental management systems (EMS) can help companies identify and reduce their environmental impact.

The state of the environment in the Combeima basin is affected by pollution and deforestation. Businesses can contribute to improving this state by investing in ecological restoration and water resource conservation projects. Collaboration with non-governmental organizations and local communities to implement reforestation initiatives can be an effective way to restore damaged ecosystems and improve water quality.

The impacts of economic activities are significant and can affect the health of ecosystems and local communities. Companies have a responsibility to assess and mitigate these impacts through corporate social responsibility (CSR). This includes not only reducing pollution but also supporting local communities through sustainable development programs that promote social and economic well-being.

The answer is where the private sector can make a significant difference. Companies can collaborate with governments and non-governmental organizations to develop initiatives that promote sustainability. This can include creating partnerships for resource management, implementing sustainability certifications, and promoting circular economy practices. Furthermore, education and awareness about the importance of sustainability can be an integral part of business strategy.

In conclusion, by integrating private sector responses into the DPSIR analysis, a more holistic and collaborative approach to sustainability in the Combeima basin can be fostered. Collaboration between the private sector, government, and local communities will not only benefit the environment but also generate economic opportunities and improve the quality of life for people in the region. Long-term sustainability in the Combeima basin depends on a joint commitment to protecting and managing natural resources responsibly.

To measure the effectiveness of the responses proposed within this framework, several indicators and metrics can be used, examples of which are:

- Concentration of pollutants in specific bodies of water.
- The rate of respiratory illnesses in a population exposed to air pollution could decrease following the implementation of emission reduction policies.
- If a recycling program is implemented, the amount of recycled waste could be measured against the total waste generated.
- In participation metrics to assess social response, surveys can be used to measure community awareness and participation in environmental initiatives. For example, the percentage of the population participating in public space cleanup programs.

These indicators and metrics not only help measure the effectiveness of responses but also allow strategies to be adjusted based on the results obtained.

Quantitative assessment of threats in the Combeima basin of the city of Ibague

Natural reserves face many different threats, including biodiversity loss due to habitat degradation and fragmentation, overexploitation of resources (Rodriguez and Leiton 2021), invasive species (Musarella et al. 2024), climate change (Price et al. 2024), and pollution (Groom et al. 2006). The assessment of these threats is usually carried out using indicators that can be taken from different sources, including bibliographic reports, field monitoring, and technologies related to remote sensing (Beresford et al. 2020). The authors used the DPSIR causal network model which was based on the drivers and pressures identified in the Combeima basin from primary data in the context of this work. Information was obtained from the literature: scientific articles, reports and other types of published materials, surveys, as done other authors (Wang et al. 2015; Gari et al. 2018). Once they were collected, a DSPIR model was built as previously described (Lin et al. 2007; De Stefano 2010; Lu et al. 2019). For the Combeima basin, data related to environmental impacts were obtained, including land use, vegetation, rivers, wildlife, parks, and nature reserves, as well as socioeconomic data, agriculture, wildlife, and tourism activities. The impacts described here include those that affect human populations and their well-being. This work used the methods already adopted by the Instituto de Investigación de Recursos Biológicos Alexander von Humboldt de Colombia (IAvH) (Mesa et al. 2016) for the assessment of threats in ecosystems.

This approach assesses threats that could lead to alterations of three essential components of the system: 1. Ecological status of aquatic ecosystems; 2. Ecological status of terrestrial habitats; and 3. Biodiversity loss (Barriga and Portocarrero 2016). Variables classified as threatened are categorized between 0 and 3, and if not present, the value is (0), low (1), medium (2), and high (3). These categories were given by IAVH experts. Once the scores were assigned to the study area, based on the pressure and impact drivers identified in the first DPSIR framework, the calculations of the total threat values (CTTV) of the three components were performed as described in expression:

$$CTTV = (\Sigma \text{ threat } (1) \times 0.35) + (\Sigma \text{ threats } (2) \times 0.35) + (\Sigma \text{ threats } (3) \times 0.30) \quad (1)$$

The identified threats were assessed using two approaches, providing relevant data to characterize the environmental state and current system functions.

Results

Causal network model (DPSIR)

The results obtained from the evaluation through the DPSIR framework for the Combeima basin are shown in greater detail and by categories the five components of the framework such as the drivers, pressures, state, impacts and responses identified in the causal network model developed for the study area of the Combeima basin are shown in the Fig. 2 and Table 1.

The following analysis through the DPSIR framework shows that the critical pressures in the region include visitor and vehicular pressures, changes in animal

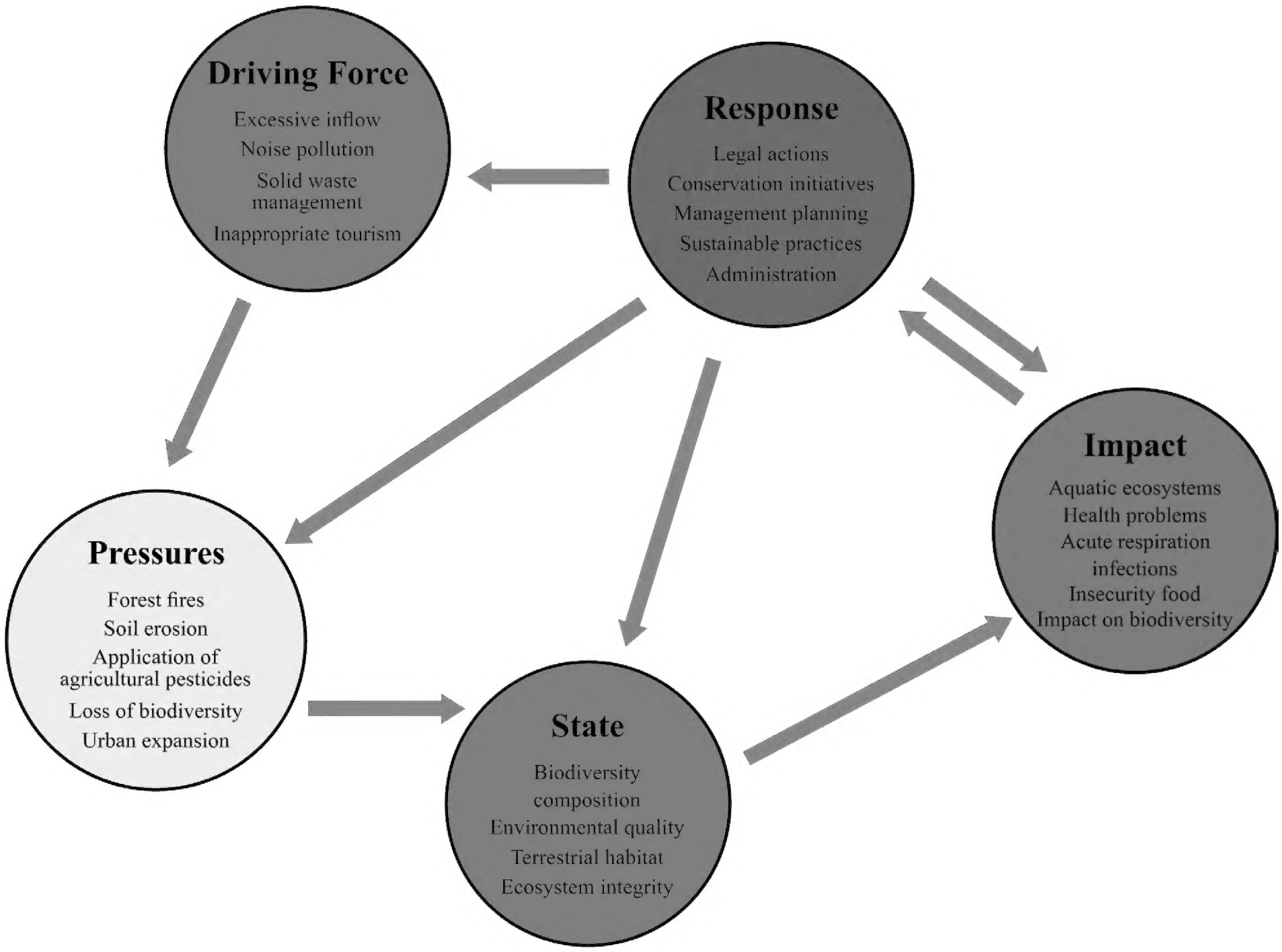

Figure 2. Graph of DPSIR framework results and hazard perception in the Combeima basin. Source author.

behavior, tour package offerings, development of facilities and services for visitors, tourists increase, sustenance mining, deforestation, inadequate or excessive use of pesticides and fertilizers in agro-ecosystems, chemical and microbiological contamination, trips to tourist sites, lack of road management, trips implementation, "pot walks", forest fires, erosion. The main drivers also involve souvenirs, climatic risks, a force that influences human impact in the Combeima basin (Table 1).

The factors mentioned have generated a decrease in ecosystem services, a decrease in water flows, a reduction in biodiversity, loss of territory, reduction of forests, generating problems in the protected areas of the Combeima basin, compromising the social part of the region such as food and water security, health problems, displacement of territory, loss of autonomy, traditional knowledge among others (Table 1).

The main responses from the departmental and local government correspond to the legal branch, through the different existing laws (Table 2).

The following paper describes four public policy instruments that encourage tourist management for the Combeima basin, where territorial planning and actions for sustainable administration lineaments are given. Furthermore, the articulation of environmental and territorial instruments in the area are required for the systematic operation of the territory and the contribution to solving conflicts due to the overlapping uses for the environmental preservation and restoration on the intrinsic use of the local community in soil management, hydraulic resources and ecosystemic services (Table 2).

Table 1. Causal network: Driver-Pressure-State-Impact-Response (DPSIR) of the Combeima basin.

Driving force	Pressures	Environmental status	Human impacts	Responses or emergencies
Excessive inflow	Pressure of people and vehicles	Damage to vegetationcover	Food and water insecurity.	Limit visitor access
	Change in behavior of animals	vegetation cover.	Health problems.	Expand tourism capacity
		Soil erosion		
		Loss of biodiversity.		
Excessive development	Offering tourism packages	Habitat reduction	Shortage of drink king water.	Dispersing visitors to other areas and attractions.
	Development of facilities and services for visitors to the Combeima watershed	Destruction of vegetation	Shortage of food.	Improvements and rehabilitations
		Erosion and deterioration of watercourses	There is malnutrition in human beings.	Land use planning land qualification regulations.
		Aesthetic effect (visual pollution)	Increase of diseases.	
			Loss of interruptions of traditions and customs.	
Noise pollution	Increase of tourists.	Pollution of the soundscape.	Irritation of the inhabitants	Awareness campaign
	Offering of tourist packages.	Disturbance of wildlife	Hearing diseases	Regulation
				Limiting visitor access
Solid waste	Increased number of tourists.	Habituation of fauna to feed on garbage	Health hazard.	Awareness campaign
	Waste production and garbage dumping.	Littering	Acute respiratory infections	Regulation
	Chemical and microbiological pollution.	Alteration of the landscape.	Diarrhea, dengue fever	Waste containers in appropriate places.
		Visual pollution.		
		Water, soil and air pollution		
		Risk of damming of water courses		
Road saturation	Tours to tourist sites.	Impact on wildlife.	Danger to humans due to accidents.	Increased supply of public transportation
	Lack of road control.	Damage to roads or trails		Development of visitor plans with environmental and conservation education
		Affection for fauna and flora		
		Atrophy of wildlife.		
Off road driving	Implementation of cycle rides. Dissemination of sports	Damage to soils, vegetation and fauna.Air and water pollution.Damage to trailsDumping of garbage	Hearing disturbanceDust pollution	Limit accessImplement or improve compliance with the rules.
Bathing in rivers or ravines	Pot walks.	Water pollution.	Depletion of water for human consumption	Environmental education campaigns.
	Excursion students.	Soil erosion.	Skin diseases.	Visitor control.
	Business tours	Dumping trash		Enforcing the rules.
		Damage to plant coverage.		
		Damage to forests.		
		Disturbance of wildlife		
Climate risk	Changes in temperature and precipitation patterns.	Scarcity of water and water stress.	Insecurity food.	National measures against change climatic
	Forest fires.	Reduction of habitats and decline in the	Displacements.	Provide reforestation programs in the most critical areas.
	Soil erosion.	richness of species.		Generate comprehensive programs for the management of highly sensitive ecosystems in national development plans.
		Frequent fires forests and landslides.		
		Climate events dangerous.		
		Soil erosion.		
Hunting and fishing	Hunting and fishing programs	Loss of resources genetic.	Impact of vegetation and soil.	Restrict access
	Purchase of animals from hunting and fishing.		Impact on biodiversity	Environmental education programs
				Enforce environmental standards

Driving force	Pressures	Environmental status	Human impacts	Responses or emergencies
Walking safari	Walks through mountains	Disturbance of fauna and flora	Irritation of human beings	Opening or modification of trails
	Excursions schools	Road erosion	Shortage of food	Restrict access
		Garbage waste.		Environmental education programs.
		Water and soil pollution		
		Contamination of the edaphic biota.		
Collection of memories	Invitation to take outhuacas.	Restriction of natural objects in danger of disappearance: Coral, shell, horns, exotic plants etc.	Water shortage	Environmental education and awareness campaigns.
	Sale of plants exotic	Alteration of the soil, flora		Restrictive legislation.
	Collection of natural objects	Water pollution		
Hot spring pollution	Pot walks	Water, soil and airPollution	Stomach damage	Environmental education campaigns
	Student field trips.	Affecting wildlife	Skin diseases	Environmental education campaigns
	Increased production of plastic and food waste	Visual impact		Construction of wwt
	Construction of tourism facilities	Bad odors		Enforcement of environmental regulations
		Damage to vegetation coverage		Visitor control
Wastewater	Pig raising	Pollution by heavy metals	Stomach damage	Environmental education campaigns
	Tourism in protected areas	Pollution by sewage water	Skin diseases	Construction of wastewater treatment plants
	Mining operations	Affection of fauna		Enforcement of environmental regulations
	Application of agricultural pesticides	Visual impact		Visitor control.
		Bad odors.		
Agricultural systems	Use, especially inappropriate or excessive use of pesticides and fertilizers.	Soil and water pollution.	Food and watersafety.	Communitybased agroecological programs for sustainability and organic agriculture
		Land use change.		Support indigenous agriculture
		Decrease in biodiversity.		Develop a community based environmental program

It also presented the control of tourist activity in the area through the establishment of registration points, access control and/or verification of technical requirements to visitors entering in conservation and motorized patrolling areas in public spaces, especially on the road. Table 3, presents the principal tourist control mechanisms in the area:

In the Combeima basin of Ibague, current public policies focus on several strategies to mitigate the negative impacts of deforestation and mining pollution.

On one hand, reforestation and natural area conservation programs are being implemented, aiming to restore damaged ecosystems and promote biodiversity. Awareness campaigns are also being conducted to educate the community on the importance of protecting the environment and natural resources (CORTOLIMA 2018).

Regarding mining, stricter regulations are being established for mining activities to minimize water and soil contamination. This includes requirements for environmental impact studies and constant monitoring of mining operations. Only small-scale subsistence miners are allowed to extract materials such as sand, stone, slate, and gold through artisanal methods, under the supervision of CORTOLIMA, the Tolima Governor's Office, and the Ibague Mayor's Office (Mayor's Office of Ibagué 2016). In 2007, Decree 1480 was issued, prioritizing the planning and intervention of the Combeima basin due to its high environmental contribution to the municipality of Ibague (Fandiño et al. 2018).

Table 2. Instruments of public policy for tourism management in the Combeima basin.

Name	Description
Development Plan for Ibague "Ibague vibra 2020–2023"	This instrument of territorial planning of the city includes the productive and dynamic Ibagué dimension (Mayor's Office of Ibague 2020), for the revitalization of the local economy in the face of the effects of the pandemic, incorporating innovation, infrastructure and mobility as strategical axis under the Sustainable Development Goals adopted by the UN in their 2030 Agenda. It is aimed at strengthening tourism productivity and competitiveness by positioning it as a sustainable tourist destination through formalization and training, promotion of local tourism boosted by nature and the expansion of tourism infrastructure under clustered territorial planning, according to the guidelines of the Touristic Development Plan of Tolima (FONTUR 2012). In addition, the strengthening of human capital and touristic products through bilingual training, incorporation of tourism in educational projects, expansion of tourism-friendly schools and the adoption of a national tourism boosted by nature policy are proposed.
CONPES 3570 - Strategies for mitigating the risk at Río Combeima basin to guarantee water supply in Ibague.	Incorporates actions for sustainable and safe management of the Río Combeima basin through cross-institutional coordination for the prevention and mitigation of risks due to natural phenomena and management of proper response to emergencies, according to the environmental arrangement in the area.
	It establishes the following components and strategies:
	1. Risk knowledge: Conducting studies on threats, vulnerability and risks and executing mitigating action.
	2. Consideration of the risk variable in territorial planning: Characterization and regulation of soil usage in the touristic area "Ibague-Juntas" – "Villamaría-Cay"
	3. Risk reduction: Lot acquisition, riverbed recovery, management of vegetation coverage and reconversion of soil use, road recovery and public services, intervention of settlements and infrastructure in areas of non-modifiable risks, strengthening of environmental culture for the prevention and mitigation of risks.
	4. **Response to emergencies:** Contingency plans strengthening and expansion and supplementation of monitoring networks.
Prioritization of projects from the Agenda for Departmental Competitivity 2019–2022.	Prioritization of actions to reduce breaches in competitiveness and innovation in Tolima through the Project: Integral and Innovative Development of Touristic Products for Tolima: Nevados Route. It includes the following components: bilingualism, employee training, bike tourism, facades, lookouts, birdwatching, music, gastronomy, craftsmanship, sports, cultural performances, local iconic products (achiras); rescue of traditional Tolima music.
Tourism and culture Chamber of Commerce of Ibague – Clustered	Sectional articulation, local business strengthening and promoting the region as tourists destination, with the creation of business opportunities and the consolidation of the touristic project through the involvement of citizens in the Natured and Craftsmanship boosted tourism in which tourist routes pass through: Ruta Mutis, Ruta Magdalena and Ruta de Los Nevados, by location, installed physical facilities and tourist attractions (FONTUR 2012).
Administrative and Special Region Planning of the central region and the Government of Tolima.	Ibague's Mayor's office, with its participation in RAPE assumes land-use planning as the evidence and tool for the increase of productivity, competitivity, and regional sustainability in potential sectors, with the management of tourism under specialization, innovation and diversification. Regional tourism on bicycle / BICIREGION has established regional touristic routes in the area for its positioning as tourist destination.

Table 3. Control mechanisms for tourist activity in the Combeima basin.

Mechanisms	Description	Institution
Information point and access control to the Alto Combeima Forest Reserve and Los Nevados National Park.	Environmental information, access restriction to El Silencio, control and registration of access to Los Nevados-North Route PNN. Verification of associated technical requirements (physical condition, guide accompaniment and equipment).	Los Nevados National Park, CORTOLIMA, Mayor's Office of Ibagué
Police estation and motorized patrol	Motorized police patrols with security and mobility control in the area of the road axis and population centers	Metropolitan Police
Control point for environmental risk	Safety information on environmental risks, access control to critical areas, emergency and accident response.	Rescue Agency (Official Fire Department, Civil Defense)

A new land use associated with urbanization and tourism has emerged, aligned with the concept of multifunctional rural services, one of which is recreation and enjoyment of the landscape (Schroeder and Formiga 2012). This activity has become highly relevant in the Combeima River Canyon due to its strategic location and scenic beauty (Fandiño et al. 2018).

The results indicate the need to prioritize rigorous governmental measures for the conservation of the Combeima basin reserve, particularly from sustainable development approaches that effectively involve local communities and their traditional ecological knowledge. This is essential to ensure the well-being of current and future generations and to prevent the loss of biodiversity in this globally unique ecosystem.

Quantitative assessment of threats in the Combeima basin

The DPSIR assessment of threats to protected areas in the Combeima watershed revealed that of sixteen threats, six had a high score, nine had a medium score and one had a low score. The most significant threats to aquatic ecosystems are subsistence mining activities and biodiversity loss due to deforestation. Other threats include pesticide use, soil erosion, livestock farming, and unsustainable tourism, which require urgent attention (Table 4).

On the other hand, the discharge of contaminated water into rivers and streams by tourists generates high levels of contamination for water for consumption and domestic use, just as the garbage and plastics that are thrown into protected reserve areas create an impact that must be taken into account (Table 4).

Discussion

This study examines environmental problems in protected areas of the Combeima basin, including the Nevados-Ibagué Natural Park, the Juntas and Villa Restrepo Protected Reserve, the Reserva de la Sociedad Civil, and the Distrito de Conservación de Suelos de los Cerros Noroccidentales. Through two complementary approaches, a DPSIR framework was established to analyze the social, socioeconomic and political components and the assessment of threats that determined which of the pressures analyzed had the most significant impact on the system, considering a quantitative scale (Table 4).

Table 4. Scoring for ecological threats to protected areas in the Combeima watershed.

Threats	Categories				Score CC
	Null (0)	Under (1)	Medium (2)	High (3)	
1. Change in the ecological status of aquatic ecosystems (35%)					
Contaminated water	Does not exist	Outside the zone	Zone of influence	Within the ecological region	2
Subsistence mining	Does not exist	Outside the zone	Zone of influence	Within the ecological region	3
Bathing in o quebradas rivers	Does not exist	Outside the zone	Zone of influence	Within the ecological region	3
Solid waste	Does not exist	Outside the zone	Zone of influence	Within the ecological region	2
Agriculture (pesticides)	Does not exist	Homemade preparations (infrequent)	Occasional	Chemicals (frequent)	3
2. Habitat alteration (35%)					
Road saturation	Does not exist	No impact	Existence, but without evidence or proof of impact	Existence, with evidence of impact testing	3
Excessive influx of tourists	Does not exist	No impact	Tourist pressure but no impact	Excessive tourist pressure with high impact	2
Tourism over development	Does not exist	Outside the zone	Zone of influence	Within the ecological region	2
Off-road driving	Does not exist	No impact	Existence, but no evidence or proof of impact	Existence, with evidence of impact testing	2
Noise pollution	Does not exist	No impact	With and without evidence of impact	With evidence of impact	2
Collection of souvenirs	Does not exist	No impact	With and without evidence of impact	Existence with evidence of impact	3
3. Loss of biodiversity (30%)					
Deforestation (Logging)	Does not exist	Rarely	Occasional	Frequent	3
Walking safari	Does not exist	No impact	Existence, but no evidence of impact	Existence, but with evidence of impact	2
Hunting and Fishing	Does not exist	Subsistence	Commercial within the area	Commercial in and out of the area	1
Other uses of flora	Does not exist	Subsistence	Commercial within the area	Commercial in and out of the area	2
Wildlife trafficking	Does not exist	Subsistence	Commercial within the area	Commercial in and out of the area	2
Total score					**12.9%**

Note. Threat scoring for (1) Ecological status of aquatic ecosystems, (2) Habitat alteration and (3) Biodiversity loss in protected areas for the four DPSIR categories in the Combeima basin.

Negative implications of ecotourism on local communities in the Combeima basin

The Combeima basin, located in Ibague, Tolima, is an area rich in biodiversity and culture, making it an ideal location for ecotourism. Local communities play a fundamental role in ecotourism initiatives in this region.

The community and business organizations in the Combeima basin area mainly consist of rural community action boards (27), local agricultural producers' associations (15), tourism service providers (1), and non-governmental organizations (4) (Mayor's Office of Ibagué 2016). These organizations are characterized by an incipient organizational capacity and weak productive and social integration, which has affected the comprehensive management of territorial development and the intervention in socio-environmental issues.

Regarding solid waste in the Combeima basin, before Holy Week, 388.3 kg of waste were collected during the awareness and cleanup campaign in the Los Nevados National Natural Park (southern sector) in March 2017, and 250 kg were collected in February 2018. Common types of waste included plastics, tents, camping mattresses, clothing and footwear, packaging, and containers made of plastic, metal, and glass, as well as sanitary waste. Additionally, the disposal of up to 400 kg of waste by visitors in the protected environmental area during the low season and up to 25 m^3 of waste in the area influenced by the road axis in the section between the villages of Juntas and Villa Restrepo has been recorded (CORTOLIMA 2018).

Regarding wastewater discharges, microbiological contamination in the Combeima basin from wastewater discharges during the period 2008–2012 and 2014 did not comply with the acceptable limits for total coliforms (1000 MPN) and fecal coliforms (200 MPN) for recreational use, as established by Decree 1594 of the Ministry of Agriculture. This implies a health risk for visitors and a critical impact on the water quality for human consumption for both the local community and the urban population (Ospina 2015).

On weekends and holidays, access and mobility, without physical or technical restrictions, result in road congestion in the area due to the saturation of its carrying capacity and obstruction caused by parked vehicles. This leads to air pollution, noise pollution, and an increased risk of accidents. It was determined that at least 1863 means of transportation circulate on Sundays, with the following distribution: 100 public collective motorized vehicles, including Buses (64%), Jeeps (24%), and Taxis (12%); 1042 private motorized vehicles, including Cars (59%) and Motorcycles (41%); and 721 individual non-motorized means of transportation, including Bicycles (97%) and Walking (3%), with numbers increasing during vacation periods and holidays (Mayor's Office of Ibagué 2016).

In conclusion, local communities in the Combeima basin benefit from ecotourism through job creation, support for local businesses, and the promotion of environmental conservation and local culture. On the other hand, it can also present challenges, such as the overuse of natural resources, changes in cultural traditions, and the need to sustainably manage tourist flows.

Environmental and social problems of tourism in the Combeima basin

In different periods, the Combeima basin has experienced significant changes in the environmental threats associated with tourism activity, as shown in Table 5.

This table summarizes the environmental threats and their impacts on the Combeima basin over different periods, highlighting the evolving situation and the need for a sustainable approach to tourism.

It was found that most vehicles and visitors are located in the zone of influence of protected areas nearing the Combeima basin, causing a quantitative rating according to the DPSIR model for medium in grade 2, which rates it as tourist pressure that doesn't generate any impact, which requires larger control from state entities (Tabla 4). A different study at Teide National Park (Tenerife) analyzed the flow of visitors and vehicles to identify the causes of a possible sensation that tourism was excessive. This serves as a manifestation of the pressing need for measures that protect the conditions of the National Park to preserve not only the space, but the environment, the population, companies and visitors with measures that can be implemented in management (Fernandez 2022). In another research, the impact of the number of visits the Cruz del Carmen area from Anaga Rural Park in Tenerife was exposed. This established a series of measures that mitigate the current congestion of vehicles and visitors in zones deemed inadequate, prohibited even, and as such, serves as an example to other protection figures at Tenerife Island. Tourism has been rising exponentially since 2006 through 2020, which brings an increase in the massification of the place of analysis. (Marrero 2021). Caviedes and Olaya, in their article, describe the conditions in which ecotourism currently develops and the requirements for its sustainability. It presents the different environmental, sociocultural and economic impacts generated by ecotourism and identified– under the assessment of a group of representatives, experts of different tourism-related entities and protected areas as well as certificates of tourist quality and environmental sustainability granted by the adoption of NTS-TS norms and the Sistema de Gestión Ambiental under norm ISO 14001-2015, which, in this industry, would influence the environments of preserved areas (Caviedes and Olaya 2018). Research was carried out in Cihuatlán, located down the southern coast of Jalisco (Mexico) through indicators of Pressure-State-Response and Pressure-State-Impact-Answer. In this research, regarding responses, the inefficient application of pre-existing laws on environmental management stood out, as well as the lack of importance placed on protecting and respecting the environment, particularly amongst local public figures (Vasquez and Garcia 2022). Another study that reinforces previous conclusions is that the impacts of visitors to a natural space cannot only be measured in physical terms but also carry a significant social component. Social load capacity refers to the sensation of exhaustion that people who visit certain places experience when being surrounded by a high level of visitors. Through a determined level of overcrowding, the experience tends to be rated as negative, independently of the scenery and natural virtues of the place they visited. This aspect must be considered in the tourist activity planning process (Blanco and Benayas 1998). On the other hand, negative impacts in ANPs could be due to overcrowding in determined

Table 5. Environmental hazards and impacts in different periods.

Period	Environmental threats	Impact
Before 2000	Emerging tourism	Low pressure on natural resources.
	Indiscriminate collection of flora.	Initial negative effects on local biodiversity
	Contamination of water sources by waste.	
2000–2010	Increased tourist interest.	Intensification of soil erosion.
	Increase in the construction of trails and tourist infrastructure.	Decline of native species and habitat degradation.
	Pollution by solid waste and wastewater.	Negative impact on local communities.
2010–2020	Implementation of conservation regulations and programs.	Environmental management progress, but persistent threats
	Mass tourism during peak periods.	Congestion and pressure on water resources.
	Lack of education and awareness among visitors.	Continued pollution and environmental degradation.
2020-Present	Impact of the COVID-19 pandemic on tourism.	Reemergence of threats with the return of tourism
	Increased use of disposable plastics	Urgency of a sustainable and responsible approach to tourism.
	Lack of adequate infrastructure for waste management.	Need to involve local communities in tourism management.
	Climate change effects in the basin	Water shortages and other environmental problems are exacerbated.

seasons in which the activities performed are not controlled as they should be, by the area administration. This which could also be linked to the social load capacity; meaning, the number of individuals the ecosystem is able to tolerate in a determined period (Zelenka and Kacetl 2014).

The Combeima basin has had an important development in tourism and preservation of protected areas, considering that there are about 26 tourist sites in which visitors can perform nature-boosted tourism. Using data obtained from the assessment of threats in protected areas, it an alteration in the ecological habitat was found. This was rated as mild in the zone of influence of the Combeima basin (Table 4), as a consequence of the offering of tourism packets and the development of new facilities and services for visitors, which has had an impact on the environment due to the excessive arrival of visitors. Therefore, it is required with the utmost urgency that government institutions send visitors to other areas with different attractions and comply with the planning of soil use for the Combeima basin. In an investigation on environmental impact, it was established that for tourism, the assessment of its impact was considered, ultimately, from an economic standpoint. Nowadays, the impact of tourism is valued also in its socio-economic and environmental variables (UNESCO 1975; Smith 1977; Murphy 1987; Pearce 1987; Mathieson and Wall 1988; Pearce and Acerenza 1988; Lozano 1990). At JADEN University in Spain, research on tourism was developed to assess indicators for the management of sustainable tourism in protected areas, where a series of measures that allowed tourism-related activity management was adopted to balance out the growing development of tourism. The goal of the paper is to establish the aims of tourism with the respective analysis and selection of indicators that meet expectations of all those interested, especially in JADEN protected areas. In conclusion, a presentation of the most relevant ideas and aspects is presented because of the making of this research (Lopez 2019). In other studies, in the last 30 years, some ideas in the tourism sector about a sustainable model have arisen as a consequence of the increase in the arrival of tourists and the intensification of domestic tourism (PNUMA and OMT 2006). A new model

of environmental indicators is called DSPR, "this model includes causes of pressure (economic and demographic growth, gentrification, farming intensification.) and the impacts and consequences of state modifications in environmental conditions in the actual medium or human health" (Vera et al. 2001). Currently, the great challenge protected areas face is how to transform into sustainable landscapes. "A park can only genuinely be if all activities, including tourism, are settled on a sustainable basis" (Lew 2010).

Additionally, in the Combeima basin, pollution has occurred in protected areas due to the noise of cars, motorbikes, construction sites and air traffic, directly impacting predators and birds. According to the quantitative assessment of ecological threats in the DPSIR framework, it was categorized as medium in second degree, in which there is pollution, but no evidence (Table 4). Other works seek to notice the impact that noise pollution represents to flora and fauna in protected natural spaces, as well as the difficulty in its treatment due to its cross-cutting nature and the pre-existing regulations. To facilitate an approach to the topic, the notion of noise pollution and protected natural spaces should be delimited and solutions to this issue should be promptly proposed (Zaballos 2020). On the other hand, the rise of noise levels reduces the distance and area in which acoustic signals can be perceived by animals; therefore, reducing the sensory capacity to generate responses to that stimulus (Barber et al. 2010). As for studies on natural protected spaces, it would be relevant, besides encouraging research given the increase of tourist inflow, if there were greater citizen awareness in terms of noise pollution, so that they are conscious of the devastating consequences of this problem in the environment and increase the visibility of its impact (Buxton et al. 2017). Studies on noise pollution in schools are generating a negative impact on health, identifying solutions with adjustments to school infrastructure and environmental pedagogic strategies (Angulo et al. 2025). To corroborate the aforementioned, we have the study for the assessment of noise pollution due to automotors that circulate in National Park Braulio Carrillo in Costa Rica. Results indicate that the presence of noise from traffic is a polluting agent in the protected area (Campos 2022).

High pollution by solid waste such as plastics, styrofoam, garbage, glass, food waste, fruit and vegetable peels, cans, and others also impact the environment, and through quantitative assessment of the DPSIR model employed in the research project showed a medium rating, where solid waste are found in the zone of influence (Tabla 4). To deal with it, it has been registered waste disposal up to 400 kg from visitors in low season, and up to 25 m^3 of waste on the road connecting Juntas and Villa Restrepo (CORTOLIMA 2016).

Below are the leading causes of waste pollution in the area:

- Lack of knowledge of responsible consumption practices and waste management by the local community and visitors.
- Weak capacity for waste organization and management, mainly in the separation of waste at source and its use.
- Lack of equipment and signage for the collection, storage, use, and transfer of waste.
- Weak institutional capacity to promote and monitor compliance with environ-mental and tourism sustainability requirements in the purchase, consumption, and management of waste products and materials in tourism activities.

Other research projects have found problems in solid waste disposal generated by adventure-boosted tourism at Huascarán National Park, which has been analysed by Huamaní (1998), which reports an average of waste in the following fashion: 48% metals (cans), 40% plastics, 6% paper and 5% glass. One of the characteristics of these wastes are their widespread disposal in roads and their relative concentration in camps, aspects that would hinder their collection (Tinoco 2003). In research at Los Venados Park in Mexico, it was identified that glass and plastics are the solid waste generated the most by tourists (Legorreta and Osorio 2011). In another research carried out at Cihuatlán in Jalisco (Mexico) through Pressure-State-Response indicators and Pressure-State-Impact-Response (FPEIR) conducting forces the inadequate the inadequate management of waste was identified as a main problem. Other pressures are related to the degradation of the ecosystems, high flux of visitors and diversity, vulnerability in the face of climate change and air pollution (Vasquez and Garcia 2022). In a study on the integrated management of solid waste and its contribution to the environmental impact on the National Protected Punta Salinas Reservoir, Huacho, it was found that the main zones destined for fishing are conformed by rocks. It was found that these areas abound with fishing and therefore there is a large flow of people, who are the generators of solid waste. Besides, in beach areas it was determined that the accumulation of waste comes from the sea due to the low flux of people. During monitoring at Guarda Islands, it was determined that each person has a per capita output of, on average, 0.4235 kg a day (Silva 2022). In additional research, it was found that the presence of inorganic waste, observed during the assessment of buffer zones, mainly plastic bags (57%), represents the highest percentage out of four months' worth of research, while aluminum cans (11%) held the second place, and the third, plastic bottles (8%). According to this author, wastes and their decomposition in time alter these areas and are clear evidence of the impact of humankind on them (Villalobos et al. 2017).

As for the contamination of the Comebima river, through which many creeks run, it is the main river that runs through Ibague. These waters are used for consumption, sports, industry, and irrigation systems. Besides, residual waters also end up at this place, creating high pollution levels, and that, according to the quantitative assessment carried out, corresponds to a medium rating (Table 4). Studies on microbiological contamination also establish the dangers these waters pose for human consumption. As a supply source, under the classification of the quality levels, according to minimal parameters of microbiological analysis, it is considered as "highly deficient" for showing average monthly figures higher than 5000 NMP of CT (Ministry of Economic Development 2000). Studies regarding first-contact recreational use given the tourist vocation that exists within the high basin, and the microbiological contamination obtained during the time period 2008–2012, concluded that they do not comply with what is established in the Decree 1594. In this decree, regulated for this purpose the admissible values of Ctes 1000 NMP and Cf are 200 NMP (Ministry of Agriculture and Rural Development 1984), whose total absence of control implies a health risk in those who go to visit (Ospina 2015). To this day, the discharge of wastewater and sewage causes an environmental impact due to the pollution of hydraulic resources with the following effects: impairment of aquatic ecosystems, loss of ambiental quality and deterioration of sustainable

and competitive development of the area as nature-boosted tourism, given that the discharge of wastewater in bodies of water directly causes the reduction of oxygen transfer, alteration of the pH, eutrophication and sludge deposition (ICONTEC 2009). In a study done in Panamá, the authors present an analysis of the main polluting agents in La Villa River, and their impact on water quality. Other authors identify and classify said agents into four categories: metals, chemical products, microorganism pathogens, nutrients and sediments. Besides, they analyse the impact of these polluting agents on the water quality, considering parameters such as toxicity, biodegradability, and their persistence in the environment (Arosemena et al. 2024). A different author establishes other pollutants in La Villa River, such as the discharge of industrial, domestic, and farming-related waste. The authors also propose measures to reduce pollution and improve water quality, like the implementation of wastewater treatment and the use of sustainable farming practices (Camarena et al. 2024). Another study on water quality and its relation to the renal health of inhabitants of the Panamean coast indicates how water pollution, mostly due to human activity, affects individual and collective health with heavy metals, pesticides, and high saline levels, which produces the development of chronic renal diseases and gastrointestinal illnesses. Therefore, it is paramount to implement public policies that regulate contamination, improve sanitary infrastructure and promote environmental education in these communities (Rivera et al. 2025).

The area of environmental protection of the Combeima basin presents a preserved area that stretches about 9238,39 ha (Mayor's Office of Ibagué 2013), These areas are heavily affected by deforestation to widen terrain for farming. Furthermore, these areas are being deforested to build tourist facilities and sports areas, which has produced an assessment of ecological threats under the DPSIR framework, with a high rating, which tells us that deforestation in this area is frequent, causing a major problem due to water pollution and destabilization of the land caused by soil erosion (Tabla 4). Other studies carried out in Panamá on La Villa River establish that deforestation, as well as pollution and other factors, play an important role in the quality and availability of water in the River (Camarena et al. 2024). On the other hand, the fragmentation of forests is a grave issue, mainly responsible for deforestation and human activity, which results in the division of large forest areas into smaller, more isolated fragments. This practice entails negative consequences like the loss of biodiversity, the alteration of ecosystems and the decrease of carbon storage (Soto 2022). It is also established that fragmentation broadens the effects of the environment in forest borders, altering micro-climatic conditions and favoring the invasion of non-native species (Kanashiro et al. 2002). It is important to notice that fragmentation of forests due to human activity leads to soil erosion, loss of biomass, prevents the habitat connectivity, avoiding normal movement of wildlife and genetic flow (Caballero 2023). Livestock farming is one of the main causes of deforestation in Panamá and Santa Fé. Cutting and burning of forests for farming projects and the high-mortality rate of herbicides and insecticides used for farming contributes to the destruction of natural ecosystems (Florez and Grajales 2017; Delgado and Granada 2019). Therefore, it is necessary to promote its conservation and sustainable use through paid environmental services, sustainable forest management and rehabilitation of forests in order to improve living conditions of the population and guarantee sustainability in forest ecosystems (Cordero 2011).

On the other hand, visitors that come to the Combeima basin can enjoy about 26 natural tourist sites, such as the thermal waters of el Rancho, creeks, waterfalls, recreational places and others. According to quantitative ecological threats through the DPSIR framework, it presented a high rating in a third degree, caused impacts throughout the entire basin, polluting waters, creating environmental and sanitary risks, ecosystem degradation, fire risks, waste generation, riverbeds pollution, soil pollution, environmental deterioration, and degradation of foliage, among others (Tabla 4). It requires with urgency a deconcentration of the influx of visitors and its redistribution in the area to ensure its ecological role of buffering and provisioning hydraulic resources and ecosystemic services for Ibague. Some studies confirm the aforementioned in Easter Island, which was attributed to economic spikes, but at the same time generated irreversible environmental damage to its territory. The government focused on the growth of the island, without foreseeing the environmental impacts that would stem from it (Perez and Rodriguez 2011). On the opposite side, hydraulic pollution in Latin America and the Caribbean is dominated by local discharge from domestic or industrial origin, followed by mining. Said discharges constitute a diverse mix of substances and compounds that represent about 90%-95% of pollution that directly affects coastal areas, and it is estimated that barely 2% of these are treated (PNUMA 2000). In other studies, it was reported that rivers often concentrate polluting agents from visitors that are trapped in riverbeds, where highly sensitive ecosystems exist, which are important for species reproduction (Kramer et al. 2001). It is reported that 37% of freshwater fish species are at risk, as well as 67% of mollusks, 53% of crustaceans, 40% of amphibians and an important number of birds and vegetation (IUCN 2000). The present investigation allowed the discovery of the issue found through the coast of the Libertad region in Perú, through the assessment of sanitary quality in coastal resorts in the area. Frameworks were given for environmental management to be focused on the recovery of unhealthy resorts during 2018 and 2019, and the proposal of a framework based on sanitary quality recovery related activities in coastal resorts and the involvement of users for its preservation (Quintana and Alva 2023).

Different kinds of crops that use pesticides and pollute hydraulic sources in the Combeima basin are considered, creating changes in soil use, soil and water contamination and the decrease of biodiversity. Through the assessment of ecological threats under the DPSIR framework, a high rating in third degree was generated, which indicates that farms frequently use pesticides to fertilize and fight plagues and illnesses in their crops and livestock. Studies indicate that the farming activity is an ever-growing source of contamination (Tabla 4). It is responsible for the introduction of fertilizers, pesticides and sediments to coastal waters through rivers. The pesticide run-off leads to the contamination of superficial waters and biota, dysfunction of ecological systems due to loss of big predators due to damages and speed of growth, impacts on public health thanks to the consumption of polluted organisms, considering that pesticides can be transported like aerosols to distances as great as 1000 km from the site of application (Escobar 2002). Agricultural research corroborates what was previously said that countries generate high discharge to rivers, sources of phosphates and nitrates in quantities amassing 1.6 million of tons a year. The greater part of these come from agricultural runoffs from the American

Midwest (Rodriguez and Espejel 2001). Other studies indicate that, in Costa Rica, 70% of water pollution produced for agriculture is due to coffee waste. The most contaminated riverbeds are those of Grande de Tárcoles and Grande de Térraba rivers, whose discharges also affect oceanic waters from the Gulf of Nicosia. In the Southeastern Pacific, the presence of pesticides has been associated with agricultural runoff. In Colombia, coffee-related activity generates approximately a charge of 3.7 million a year DBO (Escobar 2001). Other studies also show that agricultural pesticides also affect bees. The study took place in Colima, west of Mexico, and it has the objective of assessing the occurrence, temporal variability, spatial variability, and potential risk for bees and human consumption of honey affected by pesticides. The research considered two variables: the categorization of soil use (irrigated agriculture, rainfed agriculture, pastureland and forestry area) and location (coast, valley and mountain) (Rodriguez et al. 2024). The research on organochlorine and polychlorinated biphenyls pesticides in high mountain lakes of protected areas of the Toluca Nevado reinforced what was mentioned in this research, namely that pesticides are of high risk for health and the environment due to their cancerogenous characteristics, as well as their ability to bioaccumulate and biomagnify. Although its prohibition and control has happened for about 50 years, its presence has been revealed in different places in the world including high mountain areas, which is why it is important to assess the possible risks (Garcia 2021).

Conclusions

This territory has a socio-productive system characterized by agricultural, silvopastoral, and non-metallic materials extraction activities and emerging tourist activity based on a gastronomy route and complementary nature tourism offering during weekends and holidays, which has determined its physical transformation and spontaneous densification.

It is a strategic area for conservation due to its provision of ecosystem services such as water, food, and natural materials; climate regulation and support of the rural population's cultural identity; and natural environments for tourism and recreation.

The tourism area in the Combeima region faces challenges due to its emerging nature, natural growth, low productivity and inadequate commercial management. The region's low tourist importance, the division of the tourist offer, and its poor promotion and sales hinder its growth as a tourist destination. The geographical location, connectivity, landscape, biosphere, and ecosystem services also hinder its growth. The absence of a tourism information management system has caused local tourism demand to be low and irregular, with only 4.12% of participation in the departmental GDP and 50.78% of hotel occupancy in 2015 (CCI 2017).

It has been identified that the number of encounters between visitors increases in non-specialized tourist activities, in sites located in public recreational and tourist spaces in populated centers and natural areas, concentrated in parks, viewpoints, pedestrian paths, and water-round zones with tourist use in the Combeima River and its tributaries, la Perla, la González, la Plata, and Cay.

Likewise, the number of encounters with the local community increases with the visitor's stay in the population centers and their movement along the network of tertiary roads and trails in the agricultural production areas in natural areas. This has generated an impact due to the loss of their culture and customs.

The analysis of the use and transformation of tourism in the Combeima basin area establishes that tourist facilities and holiday homes have caused a dynamic occupation and transformation of the territory, with alterations in the composition of vegetation, overcrowding, disintegrated architectural development, reduction of tourist use and major changes associated with the fragmentation of natural vegetation, change in soil structure, conflicts with conservation, environmental risks, densification and conflicts of use with tourism and recreation.

In terms of conservation, biological functions need to be better supported through the expansion of the protected area. This can be done through zoning, identifying the transition zones and buffer zones needed by the reserve (Biswal et al. 2013), including those lands with significant threats but not yet protected, in particular, the lower parts of the Combeima basin inhabited by coffee farmers especially.

Since the Combeima basin is of great importance due to its protected areas, which contain important fauna species and forest areas with native species of the region that conserve water resources, the Corporación Autónoma del Tolima y Municipio de Ibagué must strictly control tourists.

The DPSIR model reveals that critical pressures in the Combeima basin of Ibagué are linked to mining, deforestation, pesticide use, poor water management, unsustainable agricultural systems, transportation, tourism, urbanization, forest fires, glacier loss, soil erosion, and human impact (Tabla 4).

The DPSIR assessment of threats in the protected areas of the Combeima watershed shows that most threats, especially subsistence mining activities and deforestation, have high and medium ratings, indicating a significant impact on aquatic ecosystems. The presence of multiple threats that require urgent attention highlights the need to implement management and conservation strategies that address both human activities and their effects on biodiversity and the quality of water resources, thus ensuring the long-term protection of these ecosystems.

The DPSIR model is useful for identifying the different behaviors that generate pressures on the system, but the lack of quantitative data limits our ability to understand cause-effect relationships more fully. This affects the assessment of important issues such as water pollution and health impacts from pesticide use, which in turn can make it difficult to make informed decisions to protect ecosystem services (Wright et al. 2017).

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Conflict of interest

The authors have declared that no competing interests exist.

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Data availability

All of the data that support the findings of this study are available in the main text.

References

Alderman CL (1991) Privately owned lands: Their role in nature tourism, education, and conservation. Ecotourism and Resource Conservation 1: 289–323.

André P, Delisle CE, Revéret JP (2004) Environmental assessment for sustainable development: Processes, actors and practice, Montreal, Presses Internationales Polytechniques, 52, 54, 157 pp.

Angulo YR, Sinisterra E, Garcia L (2025) Environmental awareness about noise pollution: A literatura review from the educational and urban context. Latin Science 9(1): 518–551. https://doi.org/10.37811/cl_rcm.v9i1.15740

Arosemena LE, Camarena FH, Saucedo E (2024) Impacts of solid waste on the water source of the Colmón de Macaracas forest. Redes (Bernal) 16: 75–91. https://doi.org/10.57819/h8wf-1594

Ávila DM, Rosas OC, Tarango LA, Martínez JF, Santoyo E (2011) Knowledge, use and cultural value of six prey of jaguar (*Panthera onca*) and their relationship with this species in San Nicolas de los Montes, San Luis Potosí, Mexico. Mexican Journal of Biodiversity 82: 1020–1028. https://doi.org/10.22201/ib.20078706e.2011.3.685

Backman KF, Potts TD (1993) Profiling nature-based travelers: southeastern market segments. Unpublished report, Strom Thurmond Institute, Clemson University, USA.

Barber JR, Crooks GL, Fristrup KM (2010) The cost of chronic noise exposure for terrestrial organisms. Trends in Ecology & Evolution 25(3): 180–189. https://doi.org/10.1016/j.tree.2009.08.002

Barriga J, Portocarrero M (2016) Hazard assessment analysis in the study area. 1. In: Mesa-SL, Santamaría M, García H, Aguilar-Cano J (Eds) Biodiversity catalog of the Caribbean region. Vol. 3. Series Environmental planning for biodiversity conservation in Ecopetrol's operational areas IAVH. Bogotá, Colombia, 203–211.

Ben Mahmoud K, Mezzapesa GN, Abdelkefi F, Perrino EV (2024) Nutritional value and functional properties of an underexploited Tunisian wild beet (Beta macrocarpa

Guss.) in relation to soil characteristics. Euro-Mediterranean Journal for Environmental Integration 9: 705–720. https://doi.org/10.1007/s41207-024-00468-5

Beresford A, Donald P, Buchanana G (2020) Repeatable and standardized monitoring of threats to Key Biodiversity Areas in Africa using Google Earth Engine. Ecological Indicators 109: 105763. https://doi.org/10.1016/j.ecolind.2019.105763

Biswal A, Jeyaram A, Mukherjee S, Kumar U (2013) Ecological significance of core, buffer and transition boundaries in biosphere reserve: A remote sensing study in Similipal, Odisha, India. Computational Ecology and Software 3(4): 126–137. https://doi.org/10.1155/2013/368419

Blanco R, Benayas J (1998) Carrying capacity studies and their contribution to establish sustainable tourism models in natural areas. Department of Ecology. World Conference on Sustainable Tourism, Autonomous University of Madrid (Spain). April 1995. Communications guide, Lanzarote-Spain, 46 pp. https://dialnet.unirioja.es/servlet/articulo?codigo=8388124

Bushell R (2003) Balancing conservation and visitation in protected areas. Nature Tourism, Environment and Territorial Management, 197–208. https://doi.org/10.1079/9780851997322.0197

Buxton RT, McKenna MF, Mennitt D, Fristrup K, Crooks K, Angeloni L, Wittemyer G (2017) Noise pollution is pervasive in U.S protected areas. Science 356(6337): 531–533. https://doi.org/10.1126/science.aah4783

Caballero CI (2023) Deforestation and its effects are analyzed by specialists and academics from the University of Panama. The University Weekly, July 2023. Digital portal, Panama City, Panama. https://launiversidad.up.ac.pa/node/3354

Camarena F, Castro J, Calderón R, Valdés B (2024) Classification of pollutants and their impact on the water quality of the La Villa river. Centers: University Scientific Journal 13(1): 38–59. https://doi.org/10.48204/j.centros.v13n1.a4633

Campos SV (2022) Evaluation of noise pollution from Route 32 on the environmental acoustics of Braulio Carrillo National Park. Degree thesis. National University of Costa Rica. http://hdl.handle.net/11056/23362

Caviedes DI, Olaya A (2018) Ecotourism in protected areas in Colombia: A review of environmental impact with emphasis on environmental sustainability standards. Journal Blue Moon 46: 311–330. https://doi.org/10.17151/luaz.2018.46.16

CCI (2017) Report economic situation of the region. Research and publications direction. Chamber of Commerce of Ibague. Ibague, Colombia, 63 pp. https://ccibague.org/estudios-economicos/

Congress of the Republic of Colombia (2020) Law 2068 of 2020. Bogota, Colombia. https://www.mincit.gov.co/getattachment/e5594015-2f7f-46c5-837a-9d3d1f-1be0b2/Ley-2068-del-31-de-diciembre-de-2020-por-el-cual-s.aspx

Cordero D (2011) Forests in Latin America. Friedrich Ebert Foundation, FES-ILDIS. Quito-Ecuador, 24 pp. https://library.fes.de/pdf-files/bueros/quito/08364.pdf

CORTOLIMA (2016) Visitors to the Combeima canyon demonstrated their environmental culture. Regional Autonomous Corporation of Tolima. Ibague, Colombia. https://www.cortolima.gov.co/sala-de-prensa/noticias/1626-visitantes-del-canon-del-combeima-demostraron-su-cultura-ambiental

CORTOLIMA (2018) Start of the first stage of the “census” in the Combeima river basin. Regional Autonomous Corporation of Tolima. Ibague, Colombia. https://www.cortolima.gov.co/boletines-prensa/inici-primera-etapa-censo-ca-n-combeima

CORTOLIMA (2019) 2.9 Protected areas. Regional Autonomous Corporation of Tolima. Ibague, Colombia, 297 pp. https://cortolima.gov.co/images/planes_y_programas/

recurso_hidrico/pomca/COELLO/2004/II_FASE_DIAGNOSTICO/J-%202.9%20ECO-SISTEMAS%20ESTRATEGICOS.pdf

Cubillos C, Jiménez Z (2011) Methodological guide for monitoring ecotourism impacts and determining acceptable carrying capacity in the National Natural Parks Unit of Colombia. National Natural Parks of Colombia. Bogotá D.C., Colombia, 117 pp.

De Stefano L (2010) International initiatives for water policy assessment: A review. Water Resources Management 24: 2449–2466. https://doi.org/10.1007/s11269-009-9562-7

Delgado DM, Granada V (2019) Environmental action plan for the "Mi Refugio" farm, Chambimbal La Campiña, municipality of Buga, Department of Valle del Cauca. Degree thesis. Faculty of Engineering, Tuluá, Valle del Cauca, Colombia. https://agris.fao.org/search/en/providers/124904/records/67122ee27f591113e2a4eaa4

Ehara M, Hyakumur K, Sato R, Kurosawa K, Araya K, Sokh H, Kohsak R (2018) Addressing maladaptive coping strategies of local communities to changes in ecosystem service provisions using the DPSIR framework. Ecological Economics 149: 226–238. https://doi.org/10.1016/j.ecolecon.2018.03.008

Elliott M, Burdon D, Atkins JP, Borja A, Cormier R, de Jonge V, Turner R (2017) "And DPSIR begat DAPSI (W) R (M)!" a unifying framework for marine environmental management. Marine Pollution Bulletin 118(1–2): 27–40. https://doi.org/10.1016/j.marpolbul.2017.03.049

Escobar RJJ (2001) Wastewater from the Northeast Pacific. Presentation at the Latin American Workshop on Municipal Wastewater Management, NUMA (ORPALC)/PNUMA-PAM, Mexico City.

Escobar J (2002) Pollution of rivers and its effects on coastal areas and the sea. CEPAL. Natural Resources and Infrastructure Division. Santiago de Chile, 68 pp. https://repositorio.cepal.org/bitstream/handle/11362/6411/1/S0210820_es.pdf

Fandiño YV, Góngora MA, Suárez LX (2018) Hidden Landscapes: A Study of Landscapes in the Upper Combeima River Basin in Ibagué. Gran Colombia University. Bogotá D.C. Colombia.

Fernandez A (2022) Analysis of the saturation processes of protected areas due to the influx of visitors, the case of the Teide National Park. Degree thesis. Faculty of Economics, Business and Tourism. La Laguna University, Tenerife, Spain. https://riull.ull.es/xmlui/bitstream/handle/915/27812/ANALISIS%20DE%20LOS%20PROCESOS%20DE%20SATURACION%20DE%20LAS%20AREAS%20PROTEGIDAS%20POR%20LA%20AFLUENCIA%20DE%20VISITANTES%20EL%20CASO%20DEL%20PARQUE%20NACIONAL%20DEL%20TEIDE.pdf?sequence=1

Florez DA, Grajales HA (2017) Environmental management plan for the farm Agropecuaria del Campo SAS, located in the village of La Tulia, in the municipality of Bolivar, Valle del Cauca. Degree thesis, Valle del Cauca Central Unit. Tulua, Colombia. http://hdl.handle.net/20.500.12993/710

FONTUR (2012) Tolima Tourism Development Plan, Colombia Tourism Promotion Fund. Bogota-Colombia, 700 pp. https://fontur.com.co/es

Garcia L (2021) Determination of organochlorine pesticides and polychlorinated biphenyls contaminants in the high mountain lakes El Sol and La Luna of the Nevado de Toluca natural protected area. Toluca Institute of Technology, Doctoral thesis, 159 pp.

Gari S, Ortiz-Guerrero C, Uribe B, Icely J, Newton A (2018) A DPSIR analysis of water uses and related water quality issues in the Colombian Alto and Medio Dagua Community Council. Water Science 32(2): 318–337. https://doi.org/10.1016/j.wsj.2018.06.001

Giongo F, Bosco-Nizeye J, Wallace GN (1994) A study of visitor management in the world's national parks and protected areas. as. Report published by Colorado State University,

The Ecotourism Society, The World Conservation Union, and The World Conservation Monitoring Centre. Available from The Ecotourism Society, North Bennington, Vermont.

Groom MJ, Meffe GK, Carroll CR (2006) Principles of Conservation Biology. 3 Eds. Sinauer Associates, Inc., Sunderland, Massachusetts-USA, 818 pp.

Guzman A, Monza X, Valenzuela S (2016) Sustainable tourism or ecotourism: A case study of the "Aurora del Palmar" private nature reserve, Entre Ríos, Argentina. RIAT 12(1): 88–104. https://riat.utalca.cl/index.php/test/article/view/337

Huamaní W (1998) Preliminary Environmental Diagnosis of Huascarán National Park. Doctoral thesis. Lima, Perú.

ICONTEC (2009) Colombian Technical Standard GTC 24: Environmental Management. Solid waste and source separation guidance. In Colombian Institute of Technical Standards and Certification. Bogota, Colombia.

IUCN (2000) Vision for Water and Nature: A World Strategy for Conservation and Sustainable Management of Water Resources in the 21th Century. Second edition. International union for conservation of nature. Gland, Switzerland.

Kanashiro M, Thompson IS, Yared JA, Loveless MD, Coventry P, Martins-da-Silva RCV, Amaral W (2002) Values of forest conservation and management: The Dendrogene Project in the Brazilian Amazon. Forest Biological Diversity. Unasylva 53(209): 25–33. https://openknowledge.fao.org/server/api/core/bitstreams/d0dace88-5d51-459d-a0ff-bcf7a76cd984/content

Kelble CR, Loomis DK, Lovelace S, Nuttle WK, Ortner PB, Fletcher P, Boyer JN (2013) The EBM-DPSER conceptual model: Integrating ecosystem services into the DPSIR framework. PLoS One 8(8): e70766. https://doi.org/10.1371/journal.pone.0070766

Kraemer AR, Choudhury K, Kampa E (2001) Protecting Water Resources: Pollution Prevention, Thematic Background Paper – International Conference on Freshwater Bonn, Secretariat of the International Conference on Freshwater, Bonn, 1–24. http://www.water-2001.de

Legorreta A, Osorio M (2011) Identification of solid waste generated by tourism in a natural protected area: the case of Parque de los Venados. The Sustainable Journey 21: 61–100. https://www.redalyc.org/articulo.oa?id=193419801004

Leung Y, Spenceley A, Hvenegaard G, Buckley R (2018) Tourism and visitor management in protected areas: Guidelines for sustainability. Best Practice Protected Area Guidelines Series No. 27, Gland, Switzerland, 1–120. https://doi.org/10.2305/IUCN.CH.2018.PAG.27.en

Lew AA (2010) Guest commentary: Tourism planning and traditional urban planning theory: the planner as an agent of social change. Leisure/Loisir 31(2): 383–391. https://doi.org/10.1080/14927713.2007.9651387

Lin T, Xiong-Zhi X, Chang-Yi L (2007) Analysis of coastal wetland changes using the "DPSIR" model: A case study in Xia-men, China. Coastal Management 35(2–3): 289–303. https://doi.org/10.1080/08920750601169592

Loiseau E, Junqua G, Roux P, Bellon-Maurel V (2012) Environmental assessment of a territory: An overview of existing tools and methods. Journal of Environmental Management 112: 213–225. https://doi.org/10.1016/j.jenvman.2012.07.024

Lopez MJ (2019) Proposal of indicators for the management of sustainable tourism in protected areas in the province of JAEN. Faculty of Social and Legal Sciences, Degree thesis. University of Jaen, Spain, 65 pp.

Lozano JP (1990) Geography of Tourism: from the contemplated space to the consumed space. First edition. Masson Publishing, Barcelona. https://www.redalyc.org/pdf/4517/451744545001.pdf

Lu W, Xu Ch, Wu J, Cheng S (2019) Ecological effect assessment based on the DP-SIR model of a polluted urban river during restoration: A case study of the Nan-fei River, China. Ecological Indicators 96(1): 146–152. https://doi.org/10.1016/j.ecolind.2018.08.054

Marrero M (2021) Visitors' perception of the overcrowding of protected areas: the case of Cruz del Carmen (Anaga Rural Park, Tenerife). Institutional repository of the University of La Laguna. Degree thesis. Santa Cruz de Tenerife, Spain. http://riull.ull.es/xmlui/handle/915/24851

Mathieson A, Wall G (1988) Tourism. Economic, physical and social impacts. Longman. Essex, 208 pp. [in Spanish, Trillas, Mexico]

Mayor's Office of Ibagué (2013) Development plan: Corregimiento 8 Villa Restrepo, human opportunities and sustainable development. Ibague, Colombia, 140 pp. https://cimpp.ibague.gov.co/wp-content/uploads/2019/04/8_Villa_Restrepo.pdf

Mayor's Office of Ibagué (2016) Development plan for the municipality of Ibague 2016–2019. Ibague, Colombia.

Mayor's Office of Ibagué (2020) Development Plan for the municipality of Ibagué "Ibague vibra 2020–2023". Ibague, Colombia. https://ibague.gov.co/portal/seccion/contenido/contenido.php?type=3&cnt=86&subtype=1&subcnt=418

Mesa L, Santamaría M, García H, Aguilar-Cano J (2016) Biodiversity catalog of the Caribbean region. Vol. 3. Environmental planning series for biodiversity conservation in Ecopetrol's operational areas. IAvH. Bogota, Colombia, 452 pp.

Ministry of Agriculture and Rural Development (1984) Decree 1594: "by which Title I of Law 9 of 1979 is partially regulated, as well as Chapter II of Title VI - Part III - Book II and Title III of Part III - Book I - of Decree-Law 2811 of 1974 regarding water uses and liquid wastes". Bogota, Colombia.

Ministry of Economic Development (2000) Resolution 1096: "Whereby the technical regulation for the drinking water and basic sanitation sector -RAS- is adopted". Bogota, Colombia.

Müller F, Burkhard B (2012) The indicator side of ecosystem services. Ecosystem Services 1: 26–30. https://doi.org/10.1016/j.ecoser.2012.06.001

Murphy PE (1987) Tourism. A community approach. First published in 1985 by Methuen, Inc. Methuen, New Yourk and London, 225 pp.

Musarella CM, Laface VLA, Angiolini C, Bacchetta G, Bajona E, Banfi E, Barone G, Biscotti N, Bonsanto D, Calvia G, Cambria S, Capuano A, Caruso G, Crisafulli A, Del Guacchio E, Di Gristina E, Domina G, Fanfarillo E, Fascetti S, Fiaschi T, Galasso G, Mascia F, Mazzacuva G, Mei G, Minissale P, Motti R, Perrino EV, Picone RM, Pinzani L, Podda L, Potenza G, Rosati L, Stinca A, Tavilla G, Villano C, Wagensommer RP, Spampinato G (2024) New alien plant taxa for Italy and Europe: An Update. Plants 13(5): 620. https://doi.org/10.3390/plants13050620

National Natural Parks of Colombia (2017) Management Plan 2017–2022 Los Nevados National Natural Park. National Natural Parks of Colombia. Western Andes Territorial Management. Bogota-Colombia. https://old.parquesnacionales.gov.co/portal/wp-content/uploads/2017/03/Plan-de-manejo-NEVADOS-Marzo_2017-1.pdf

Ospina O (2015) Analysis of microbiological contamination in the Combeima river, Ibagué (Tolima, Colombia). Cleaner + Production 10(2): 92–103. https://dialnet.unirioja.es/servlet/articulo?codigo=5746943

Pearce D (1987) Tourism today. A Geographical analysis. Longman Scientific & Tecnical. Department of Geography, University of Canterbury, New Zealand, 229 pp. https://www.cabidigitallibrary.org/doi/full/10.5555/19871842999

Pearce D, Acerenza MA (1988) Tourism development. Its planning and geographical location. Tourism development. Its planning and geographical location. Ed. Trillas, Mexico. https://www.sidalc.net/search/Record/cat-unco-ar-7408/Description

Perez M, Rodriguez C (2011) Environmental impacts generated by tourism development on Easter Island. RIAT: Interamerican Journal of the Environment and Tourism 7(1): 42–48. https://riat.utalca.cl/index.php/test/article/view/214/86

Perrino EV, Tomaselli V, Wagensommer RP, Silletti G, Esposito A, Stinca A (2022) Ophioglossum lusitanicum L.: New Records of Plant Community and 92/43/EEC Habitat in Italy. Agronomy (Basel) 12: 3188. https://doi.org/10.3390/agronomy12123188

Pinto R, de Jonge V, Neto J, Domingos T, Marques J, Patrício J (2013) Towards a DP-SIR-driven integration of ecological value, water uses, and ecosystem services for estuarine systems. Ocean and Coastal Management 72: 64–79. https://doi.org/10.1016/j.ocecoaman.2011.06.016

PNUMA (2000) Overview in: Global Environment Outlook GEF - Division of Environmental Information and Assessment and Early Warnings (DIEA and AT), PNUMA. United Nations Environment Programme, Nairobi, Kenya. http://www.unep.org

PNUMA, OMT (2006) For a more sustainable tourism. A guide for policy makers. United Nations Environment Programme, World Tourism Organization.

Price J, Warren R, Forstenhäusler N (2024) Biodiversity losses associated with global warming of 1.5 to 4 °C above pre-industrial levels in six countries. Climatic Change 177: 47. https://doi.org/10.1007/s10584-023-03666-2

Quintana F, Alva CA (2023) Environmental Management for the Recovery of the Sanitary Quality of the Coastal Resorts of the La Libertad Region. 21th LACCEI International Multi-Conference for Engineering, Education, and Technology: "Leadership in Education and Innovation in Engineering in the Framework of Global Transformation: Integration and Alliances for Integral Development", Hybrid Event, July 2023, Buenos Aires-Argentina, 1–12.

Rivera V, Perez M, Tejedor E (2025) Water Quality and its Relationship with Kidney Health of Coastal Area Inhabitants. REICIT 4(2): 50–64. https://revistas.up.ac.pa/index.php/REICIT/article/view/6749

Rodriguez OM, Espejel I (2001) Municipal Wastewater as a Terrestrial Source of Marine-Coastal Zone Pollution in the Latin American and Caribbean Region, document United Nations Environment Program PNUMA, Regional Office for Latin America ECLAC - SERIES Natural Resources and Infrastructure No. 50 and the Caribbean ORPALC and the Coordinating Office of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities GPA, Mexico.

Rodriguez J, Leiton M (2021) Loss and fragmentation of native forest ecosystems and its influence on habitat diversity in the Tropical Andes hotspot. Mexican Journal of Biodiversity 92: e923449. https://doi.org/10.22201/ib.20078706e.2021.92.3449

Rodríguez-Aguilar BA, Peregrina-Lucano AA, Ceballos-Magaña SG, Rodríguez-García A, Calderon R, Palma P, Muñiz-Valencia R (2024) Spatiotemporal variability of pesticides concentration in honeybees (*Apis mellifera*) and their honey from western Mexico. Risk assessment for honey consumption. The Science of the Total Environment 947: 174702. https://doi.org/10.1016/j.scitotenv.2024.174702

Schroeder RV, Formiga N (2012) Rural tourism as a territorial revitalization strategy. The case of southwestern Buenos Aires. Annals of Geography of the Complutense University 32(2): 369. https://doi.org/10.5209/rev_AGUC.2012.v32.n2.39725

Serrano SG (2011) Tourism in protected areas as a means to achieve sustainable development in Central America. National University of Mar del Plata. Faculty of Economic and Social Sciences. Mar del Plata, Argentina, 101 pp. http://nulan.mdp.edu.ar/id/eprint/1541

Silva J (2022) Integrated solid waste management and its contribution to the environmental impact of the protected national reserve of Punta Salinas, Huacho. José Faustino Sánchez Carrión National University. Faculty of Agricultural, Food Industry and Environmental Engineering. Thesis, Huacho-Perú, 157 pp. http://hdl.handle.net/20.500.14067/6936

Smith VL (1977) Hosts and Guests: theantropology of tourism, University of Pennsylvania Press, Philadelphia.

Soto AI (2022) Proposal of Ecological Planning Instruments in rural communities to determine the status of vulnerable ecosystems. Degree thesis. Publisher Universidad de Concepcion, Faculty of Architecture, Urbanism and Geography. Concepcion, Chile. https://repositorio.udec.cl/handle/11594/10065

Tinoco O (2003) The impacts of tourism in Peru. Industrial Data 6(1): 47–60. https://doi.org/10.15381/idata.v6i1.5982

UNESCO (United Nations Educational, Scientific and Cultural Organization) (1975) The effects of tourism on socio-cultural values. Annals of Tourism Research 4(2): 74–105. https://doi.org/10.1016/0160-7383(76)90100-6

UNWTO (1998) Introduction to Tourism. Madrid, Spain. https://www.e-unwto.org/doi/book/10.18111/9789284402694

Vasquez R, Garcia R (2022) PSR and DPSIR indicators for analysis of sustainability in the municipality of Cihuatlan, Jalisco, Mexico. Noesis, Social Sciences Magazine 27(53–1): 1–26. https://doi.org/10.20983/noesis.2018.3.1

Vera JF, Juarez C, Morte A, Tores F, Navalon M, Such M, Baños C, Martinez JE, Ivars JA (2001) Planning and management of sustainable tourism development: proposals for the creation of a system of indicators, working paper n° 1, University Institute of Geography, Alicante. University of Alicante, Spain, 75 pp.

Villalobos K, Chaves A, Barrantes J (2017) Buffer zone evaluation in protected areas: the case of Cabo Blanco absolute natural reserve. https://repositorio.una.ac.cr/bitstream/handle/11056/14180/Tesis.pdf?sequence=1&isAllowed=y

Villordo A, Rosas OCF, Clemente F, Martínez JF, Tarango LA, Mendoza G, Sánchez M, Bender L (2010) The Jaguar (*Panthera onca*) in San Luis Potosí, México. The Southwestern Naturalist 55(3): 394–402. https://doi.org/10.1894/CLG-30.1

Wagensommer RP, Bartolucci F, Fiorentino M, Licht W, Peccenini S, Perrino EV, Venanzoni R (2017) First record for the flora of Italy and lectotypification of the name Linum elegans (Linaceae). Phytotaxa 296(2): 161–170. https://doi.org/10.11646/phytotaxa.296.2.5

Wang W, Sun Y, Wu J (2015) Environmental warning system based on the DPSIR model: A practical and concise method for environmental assessment. Sustainability 10(6): 1728. https://doi.org/10.3390/su10061728

Wight PA (1996) North American ecotourism markets: Motivations, preferences and destinations. Journal of Travel Research 35(1). https://doi.org/10.1177/004728759603500102

Wright W, Eppink FV, Greenhalgh S (2017) Are ecosystem service studies presenting the right information for decision making. Ecosystem Services 25: 128–139. https://doi.org/10.1016/j.ecoser.2017.03.002

Zaballos M (2020) Noise and natural environment. Special reference to protected areas. Journal of the Jacobean Graduate School of Education 18: 79–92. http://revista.jacobea.edu.mx/

Zelenka J, Kacetl J (2014) The concept of carrying capacity in tourism. Amfiteatru Economic Journal 16(36): 641–654. https://hdl.handle.net/10419/168848